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CERAMICS IN MSL: CHALLENGES AND OPPORTUNITIES

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CERAMICS IN MSL: CHALLENGES AND OPPORTUNITIES

by

T.A. Wheat*

ABSTRACT

The current wave of international interest in ceramic materials and the projections for the future markets for some of these materials has stimulated interest in Canada in ceramics in a number of sectors including manufacturing, financial, provincial research organizations, the universities as well as other federal agencies. As a continuous contributor to the field in Canada for over 50 years - the contributions for the last 25 years being in both the traditional and advanced ceramics fields - it is appropriate that the areas of R&D activity appropriate to the CANMET facilities be examined vis a vis the expressed interested of other organizations that are entering the field so that complementary and co-operative programs are developed and duplication avoided.

This report identifies the technical strengths of the staff and facilities, and hence the opportunities for the future ceramics program in CANMET; it also addresses some concerns and restraints that have influenced this view of CANMET's future contribution to the field.

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LES CÉRAMIQUES DANS LES LSM: DÉFIS ET POSSIBILITÉS

par

T.A. Wheat*

RÉSUMÉ

En raison de l'intérêt que soulèvent actuellement les matériaux de céramique dans le monde entier et des projections relatives aux marchés futurs de certains de ces matériaux, les céramiques ont suscité au Canada un plus grand intérêt dans de nombreux secteurs d'activité, dont le secteur manufacturier, le milieu financier, les organismes provinciaux de recherche, les universités ainsi que d'autres organismes fédéraux. Pendant plus de 50 ans, le CANMET a sans cesse contribué à ce domaine au Canada, les 25 dernières années ayant été orientées vers la céramique traditionnelle et la céramique avancée. Il convient donc d'examiner les activités de R et D réalisées aux installations du CANMET par rapport à l'intérêt manifesté par d'autres organismes, nouveaux dans le domaine, afin d'établir des programmes complémentaires et coopératifs et d'éviter le chevauchement des travaux.

Le présent rapport fait ressortir les ressources techniques du personnel et des installations et démontre ainsi les possiblilités du futur programme sur les céramiques au CANMET. Il traite également de certaines préoccupations et restrictions qui ont influencé la perception du rôle que jouera le CANMET dans ce domaine.

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RECOMMENDATIONS

A. Irrespective of the facilities available, it is suggested that the Section's effort:
- in traditional ceramics continue to be less than one third the total;
- in advanced ceramics should be split between the structural and functional areas in the ratio of 1:4 to reflect the current market reality. (The most optimistic projections, only show this ratio dropping to 1:3 by the year 2000);
- in the processing and characterizing ceramics be maintained.

B. Recognising the current reality of global restraint, it is further suggested that:
- priority be given those projects that maximize the opportunity for exploitation of the R&D effort, i.e., materials that offer use in BOTH the structural and functional areas (such as partially stabilized zirconias [PSZ] and SiC) should take precedence over those having more limited applications (e,g, Sialons, Si nitride are structural materials only).

C. Within the traditional area, it is suggested that the emphasis be placed on the refractory rather than on the clay products area because:
- the opportunities for exploiting R&D in clay technology in Canada are limited:
  - the very low cost of the raw material precludes even simple beneficiation, e.g. it is not economical to remove gypsum from clay and shale in Southern Ontario to lower fluoride emissions in the stack gases of sintering furnaces;
  - the majority of the problems are site/deposit specific;
  - developments such as fast firing demand major changes in the industry such as large capital investments for roller hearth furnaces and changes to body compositions that sometimes demand adding imported raw materials. Such changes are unwelcome in a very conservative industry;
- there are only three major clay products producers in Canada and they are highly automated;
- there are demands by the steel-making industry for refractories characterization and testing under simulated conditions such as the need for evaluating the behaviour of candidate slag-line brick in speciality steel-making, c.f. Atlas Steel.

However, although the emphasis should be on refractory materials, the Ceramics Section still retains the ability to characterize various clay products and this should continue to be done for industry as-required.

D. Within the advanced materials field, it is suggested that we should:
- retain some effort in sodium solid electrolytes in support of the commercial effort by Magna International (battery) and Almax Industries (thermoelectric generator) programs;
- process, characterize and commercialize PSZ, zirconia-toughened alumina and SiC for wear- and impact-resistance applications, e.g., slurry pumps and valves;
- continue our involvement in materials for sensors such as Hyceram and the piezoelectrics;
- expand our involvement in composites (structural products such as BN-

BN, TiB_2-AlN) to include electrical composites for NDT. There is a growing interest commercially in both the structural and functional composites field in Canada to which this laboratory can contribute.

E. Assuming increased resources:

- the above principles would still be followed, however, we would cast our net wider to include "less favoured" materials such as the sialons and Si nitride. They will be vital in the future as durable cutting tools for the maximum utilization of capital invested in numerically-controlled machines (down time of capital intensive equipment due to tool failure is a critical issue)
- the area of ceramic joining technology would be addressed: ceramic-to-ceramic and ceramic-to-metal for structural applications.
- many more materials for sensors would be included. Emphasis would be on process control, feed-back (tactile) sensors for robots, micropositioning,
- the area of tribological properties and wear resistance would be addressed, particularly at high temperature
- would increase significantly (i.e. probably use a 1:1 ratio between structural and functional materials) our effort in toughened and wear resistant materials (NACMMR's 1985 recommendation to abandon this area of R&D in CANMET was ill-advised and completely counter to present commercial interests - particularly, for those materials [such as the toughened mullites, cordierites, alumina and glasses] that are of moderate cost but superior performance to those commercially available at present.)
- would increase substantially the effort in chemically bonded materials
- the opportunities and limitations of using microwave energy in all stages of processing (drying to sintering) would be addressed. This is starting to be addressed by industry (Magna, Almax).
- would reverse the present ceramic technician:professional ratio from 1:3 to 3:1
- would update our capital equipment - pre WW-II temperature controllers changed to digitally programmable units (Furnace Room) and add new facilities (injection moulding, microwave processing, mechanical properties testing, etc).

INTRODUCTION

Much has been written on ceramics in the past and much more will be in the future as these materials cover one third of all known materials (the others being metals and plastics). Ceramics and the associated technology have a profound influence on society as they are crucial to the successful development of many industries such as pyrometallurgy; metal forming, shaping and finishing; chemical and petrochemical processes; electrical and electronics; automotive; etc. and hence they are essential to a wide number of industrial sectors such as manufacturing, energy, telecommunications, data processing and transportation. This essential dependence of many industries and sectors on ceramic technology clearly shows ceramics to be one of the "enabling technologies" that are vital to the health and wealth of society.

Because of these and other profound influences that ceramics have on any technically developed country, there has been a growing international realization in the last 25 years that ceramics will play an increasingly important role in the economy of developed countries in the future. In

addition to the strong "enabling" influences above that have already spawned a vigorous world market of about $7 billion (1983) that is projected to increase to nearly $18 billion by 2000 there has also been further impetus to the massive development of ceramics since 1979 due to their potential to save energy and increasingly scarce strategic raw materials such as Cr, W, V, Mo, Nb etc. that are essential to the manufacture of super-alloys used in high-performance heat engines. Thus, although such high-temperature engineering ceramics (the so-called "structural ceramics") only presently garner about 20% of the world market, it is anticipated that the market share of structural ceramics will increase as ceramics become used more widely in a variety of heat engines. As well as having the potential to raise the operating temperature and hence the operating efficiency of Carnot-cycle limited engines, the extensive use of ceramics will also ease the pressure on the vulnerable strategic raw materials used for the super-alloys - a number of high-performance ceramics based on Si, O, N and C have already been demonstrated in experimental engines operating close to the current temperature limit of the super-alloys. For example, Nissan introduced a ceramic turbo-rotor into regular production in October 1985 based on silicon nitride that withstands 135,000 rpm at 900°C.

These factors have led the Japanese to massively increase their development of the whole spectrum of ceramic materials and to have put in place a national program of materials development that specifically identifies ceramics as the next target for development after plastics in the 1950's and the IC in the 1970's. In July 1982, they created the Japanese Fine Ceramics Association (JFCA) which presently comprises over 200 industrial member companies only 24% of whom were already in the ceramics field. Many aspects of the Japanese program, their markets and apparent strategies have been discussed elsewhere (1-5).

At present, Japan has approximately 2000 researchers (excluding management, administration or sales staff) devoted to ceramic technology; the United States has about 1000 and Europe about 300. The result of this attention is that already Japan has captured half the world's market in electrical ceramics (4) and expects to maintain that market-hold beyond the year 2000.

Because of this clear example of the benefits of nationally directed co-operative industrial programs, some of the Western countries have recently moved to emulate in part the Japanese example of forming industrial "collectives" that are patterned after the JFCA. Hence, the creation of the Ceramics Club in the U.K. in 1983, the American Ceramics Association in May 1986 and the University-Industry Council for Advanced Ceramics in Canada in June 1986. In each case, these associations will foster the formation of industrial groups with common interests in a particular area of ceramics - particularly in high-temperature engineering materials - and presumably represent their interests and the opportunities of the field to their respective governments.

In this wide-ranging field that covers from teacups to turbines and embraces the super-computer, medical instrumentation, artistic pottery and steel-making refractories, it is clear that the Ceramics Section of MSL with a staff of 11, Appendix A, can not possibly cover even the surface of the field. By default, we have already ignored large sections of the field due to lack of support for staff and facilities - a situation that is unlikely to change in

the near future. For example, we have not had capability in glass and enamels, our involvement in refractories has been limited and we have recently lost our capability in clay and shale. Clearly, we can only hope to be an effective catalyst in the field, never a reagent.

THE CURRENT SITUATION

I. Market Opportunities for Canadian Industry

The present situation has been recently reviewed in Canada for the developed countries (1-5). It is assumed that the reader is familiar with that background material. In essence, it is recognized that there is an opportunity for the development of specific areas in the ceramics field in Canada where market opportunities exist, technical capability exists and the energy rates are low (compared with other countries). The highlights of those recommendations are given in Appendix B.

In September 1986, the Office of Technical Innovation, DRIE, published a pocket booklet designed to attract foreign investment to Canada in the advanced ceramics field. The booklet is being distributed, in part, through the embassies of External Affairs.

Much closer to home, a contract was let by the Ministry of Northern Development and Mines, Ontario to Hains & Associates and MKM International funded under the Ontario MDA to assess the impact on Ontario's existing industry of the development of advanced ceramic products in the province and the displacement of some existing products such as metal wear-plates, etc. The report is due for delivery early 1987.

Noranda Research Centre is understood to have a $50k contract with the Queen's University Advanced Materials Technology Unit to assess the opportunities for use of ceramic in the mining industry.

As an example of how fast the field is moving, it is understood that Chrysler Canada will be using ceramic parts (Si nitride containing 30% alumina) in the valve-train components of their 1988 4-cylinder engines. The attraction is wear resistance coupled with lowered mass compared with metal parts. The era of the use of ceramics in the regular production of automotive products has already been scheduled ...

II. Technical R&D Capability in Ceramics in Canada

The various Canadian institutions involved in this field in the universities, provincial research organizations and the federal agencies have been reviewed elsewhere in June 1986 (4,5). In essence, there is an internationally recognized core of 50-100 researchers in the country that forms the nucleus of the industry.

Developments Since June 1986

In the intervening few months, there has been other activity in Canada, the most significant of which is the development of capability in "Advanced Industrial Materials" within the National Research Council - in the ceramics field that is centred at the Atlantic Regional Labs, Halifax. With a goal of

10-15 p-y's, staffing of two vacancies started in September 1986 with the hiring of Pat Lauzon from the Ontario Research Foundation (ORF) - a clear indication that their initial interest lies in developing structural ceramics.

Also in this period, members of Alberta Research have visited EMR to assess the optimum lab needs required to establish an advanced ceramics group in the province. The September issue of the American Ceramic Society Bulletin carries an advertisement for a newly created tenure track position in the University of Alberta for a Professor of Ceramics and Queen's University, Kingston is known to have a position open in the faculty of Chemistry - a second position was recently filled in the faculty of Metallurgy with the hiring of Dr V. Krstic as their first structural ceramist.

BC Research has recently (Sept 86) initiated work in the sol-gel processing of structural ceramics and CRIQ, Quebec City has broken out of its customary focus on traditional ceramic products based on indigenous raw materials to develop sol-gel processes for the synthesis of toughened ceramics (under contract to NRC).

Companies such as Esso, Polysar, Kennemetal, Falconbridge, Inco ... have joined the recently formed Canadian Ceramics Council indicating their growing commercial interest in the ceramics field.

III. Activities of the Ceramics Section

A. In-house Work

Despite our technical limitations noted above, we have managed to cover many aspects of ceramics in Canada in recent years including:

- the conduct of bench research and development in house and with industrial partners;
- the initiation of contracts or support for private sector proposals to various federal agencies and the monitoring of such at universities, PRO's and industry;
- the provision of technical comment for the Minister and policy formulation.

The majority of the effort in the Section falls under the first two items and although the effort, in terms of dollars, is heavily biased towards the first category, the Section has maintained for many years at least an equal effort in the second category and has been a significant influence through its consistent technical involvement in the industrial R&D programs of other agencies such as the National Research Council, Dept National Defence, Dept Regional and Industrial Expansion and the Ministry of Science and Technology, and to a lesser extent those of Dept Consumer and Corporate Affairs, Dept Indian and Northern Affairs and the Dept of Communications.

This opportunity to conduct in-house R&D, to understand the technical difficulties and some of the solutions involved while working in close liaison with commercial enterprises has been mutually beneficial. Although difficult, an attempt has been made to estimate the benefits derived from the involvement of EMR in R&D. The benefits fall in three classes: those where the work resulted in a gain to the public purse, those where the results avoided a loss from the public purse and those where a wide spectrum of individuals and organizations received unbiased professional consultations in this "enabling" technology. Examples of the first two categories, taken from the Section's

involvement in solid electrolytes and piezoelectric ceramics, are given in Appendix C; the direct benefits resulting from activities in the third category remains difficult to quantify directly.

The current ceramics R&D program is given in Appendix D. That portion conducted under the project "Advanced Ceramic Materials" has recently been broadened to include both structural and functional ceramics. The effort is not yet at the level of structural:functional = 1:4 to reflect the general market activity ... but will be when staff are reassigned from the IOC iron ore project which has largely run its course in the Ceramics Section.

B. Involvement in Industrial R&D Programs Funded by Other Departments

At present, the industrially oriented work conducted in collaboration with other departments is handled by three members: AA, AKK and TAW. Although apparently similar in nature to the role of SA for EMR contracts, this work is quite different - the individual is free of all financial and other administrative responsibilities which is always handled by the appropriate secretariat of the sponsoring departments.

The commercial activity that has ocurred in the last five years and with which members of the section have been associated as technical liaison officers with other programs such as IRAP etc are given in Appendix E. In these cases, the technology generally does not arise from CANMET programs (the exceptions have been the piezoelectrics and the ionics programs). Because of the exposure of industry to CANMET and vice versa afforded by these programs, both sides have benefited greatly.

C. EMR Contracting Out

The use of EMR contracting out and the Unsolicited Proposal progam, especially if augmented by DSS Bridge funds, has been valuable (e.g., Almax Thermoelectric Generator; NDT work with McMaster and Blue Mountain Hi-Tech; electrolyte work with Ontario Research Foundation, McMaster and Queen's; composites and structural ceramics with Electrofuel). In all cases, we have made significant contributions to these programs and hope that can continue. However, with increasing demands in other areas such as contracting in, technology transfer from the labs, reponding to the increasing number of industrial requests for information on ceramics that is occurring (both directly to EMR and indirectly through the programs of other departments, item B above), and working with industrial staff seconded to the lab we will be stretched even thinner.

D. Contracting In

With the prospect of contracting-in work to the federal labs there will clearly be a potential conflict between assisting and advising an industrial collaborator on an IRAP program (for "free") and keeping open the opportunity for contracting in some or all the work - with such an option it could be difficult to ensure that unbiased, objective assessments are made on a company for policy formulation when the carrot of contracted-in $$'s is waved before the staff.

Generally, Canadian industry is still largely a branch-plant operation (much of the R&D is conducted elsewhere). In the ceramics field the limited

opportunity for contracting R&D from industry is compounded by the fact that many of the companies are small (100 employees or less), cash poor and none of these maintain their own R&D facilities. Only IBM, Bell Northern and Murata Erie are known to maintain their own R&D labs; they all have over 1000 employees and have not been known to contract work out because they wish to develop their own proprietory information.

WHAT ARE INDUSTRY'S NEEDS?

I. The Industrial View

So far, there has been no formal indication of the industrial needs in the ceramics field. Until recently, the one organization in Canada (Canadian Ceramics Society) has been consistently quiet and low key - failing even to submit a brief during the mid 1970's when fuel allocations were being considered - and discussions with individual companies tend to focus on the financial aspects not on the technical. However, for the first time (feeling competition from the newly formed Council? - see below), there is an indication that the Society is becoming more aware of the role it can play in this field as demonstrated by last Fall's Meeting program, Appendix F.

Our past experience with NACMMR has been unsatisfactory. In committee, the field of ceramics has been consistently subordinate to the interests of mineral processors, metal-forming companies or the oil and gas industry and has therefore not been well represented. About 18 months ago, a recommendation to cancel development work on toughened ceramics was made by that committee and complied with - that set back by over two years our program in this area which is undoubtedly the most important aspect of the present international activity in the field of structural ceramics (ironic to read in Nov 1986 issue of Ceramics Industry that Champion Sparkplug have just introduced zirconia-toughened alumina - one of the products terminated). Also witness the recent activity of Trans Canada Pipelines and PMRL in SiC.

In October 1985, the Ontario Research Foundation in conjunction with the Canadian Manufacturer's Association sponsored a one-day meeting in Ottawa to discuss the development of advanced industrial materials. None of the technical staff at MSL were invited. It was hoped that this was the begining of an industrial initiative in the materials field; however, that has so far not proved to be so.

During the same period, a group of university professors headed by Dr Chaklader of UBC began to organize what on the 2/3 June 1986 became the University-Industry Council on Advanced Ceramics. The composition of that Council and some of its objectives are given in Appendix G. So far that group has succeeded in generating considerable interest as they attracted approximately 80 attendees to their inaugural June meeting without, at that point, having a stated set of objectives. It is understood that in the next few months, this organization will start deliberations on what will become their recommendations for the further development of the field in Canada.

It is significant that the political imperative felt by External Affairs to demonstrate to Japan that there is a viable ceramics activity in Canada (thereby attracting Japanese capital?) led them to fully fund the recent solo one-week visit of the first President of the "Council", Dr. P.S. Nicholson,

McMaster University, to selected Government establishments and other Associations. This only weeks prior to a trade mission to Japan.

II. The Writer's View

There are both business and technical needs of the industry. For example, there is a need:

- for an accurate profile of the industry. The last publication of "Ceramics Plants in Canada" published by EMR was made in 1976 and is now grossly inaccurate. Revisions were discontinued to minimize expenditures;

- for reliable and useful statistics on the industry. Those available from Statistics Canada do not reflect the present industry as the available catagories are far too limited and hence many of the known products, especially in the electronics area, pass unrecorded;

- for continually revised and published market data. This is particularly important as it will also educate the money markets of the opportunities and help attract capital to the industry;

- to popularize the industry at trade fairs such as the Hi-Tech Show to nullify the popular misconception that ceramics are only concerned with artware and tableware. The recent exposure of the Council at the Toronto Hi-Tech show with examples of advanced products (such as Magna's sodium-sulphur battery-powered Chrysler van, etc) is a good example;

- for government to maintain support of "seed" programs such as IRAP operated by NRC and highly regarded by industry. The recent proposal to divert major funding from that program or any other to the Space Program would be counter productive as there is essentially no market for space-processed materials and there is little chance that this situation will be reversed.

From a technical point of view, it is probable that fast-firing technology will become important as energy costs increase again in the future. The development of chemically bonded ceramics will be important in some areas where significant energy savings appear possible. Similarly microwave processing for drying all ceramics and calcining and firing some could also be important as major energy savings are possible and that technology should also offer a significant quality improvement. However, like the disbanded hydrogen program, these areas will only assume importance when the cost of energy rises again. At present, we live with the short-sighted view that the supply and the cost of energy is not a major concern.

WHAT CONSTRAINTS EXIST?

A. Policy Constraints

Budget Restraint

The Section has for some years not received its allotment of the limited capital funds available. This has been most noticeable under the NEP program where the funds allotted (OERD Green Book) and those authorized to be expended were as follows:

Year	81/82	82/83	83/84	84/85	85/86
Capital Allotted	90k	160	160	160	10
Capital Authorized	90	157	~95	~20	~4
Short Fall	0	0	65k	140k	0

The lack of opportunity to obtain new facilities and also upgrade some of the pre WW-II equipment during the period 1983 to 1985 when funding was allotted to a program in the Section continues to hamper the present programs. For example, the Section presently lacks:

- sufficient clean facilities for materials synthesis and processing;
- adequate mechanical testing equipment (will collaborate with PMRL - but they also lack high-temperature testing facilities);
- 2200C sintering facilities for SiC and Si Nitride;
- pressure slip casting and injection moulding facilities;
- microhardness (fracture toughness) facilities (those in PMRL do not have a high enough load to examine ceramic materials).
- automated data acquisition for TGA, DTA, dilatometer etc equipment.

Downsizing

The progressive reduction in the ratio of technical to professional staff coupled with a lack of the needed automated equipment seriously affects the Ceramics Section's operating efficiency. We should not have to use one of the three ceramics technicians we have left to record e.g., temperature and gauge readings for thermal expansion.

Nielson Report

What were their comments? There appears to be no contact made between the committee and the industrial organizations listed by this Section. We have managed to maintain a close liaison with industry for many years - despite a former contrary CANMET policy during the period 1975-1980.

National Advisory Committee on Mining and Metallurgical Research NACMMR

NACMMR (now the Minister's National Advisory Committee on CANMET - MNACC) is a major influence in determining EMR programs. Only recently, however, has a committee member had any knowledge of and professional involvement in the ceramics field. The selection of committee members competent in ceramics must be a priority in the future.

Conflicting Requirements of Professional Staff

The present policy of simultaneous contracting in and out is unwise. Already evidence is seen of support offered for UP's, IRAP's etc to industry followed by the request for cost-recovery for any element in the program which can be conducted in federal labs. If the trend to increased contracting-in continues, it will undoubtedly erode the independent judgement of staff.

B. Competition Elsewhere

There is increasing national and international interest in the spectrum of structural ceramics; however, there are no major changes in the various

establishments in the functional ceramics and none anticipated. Newcomers appear to be rushing into the structural materials field in the blind belief that the Japanese market projections for components in this field are accurate, i.e., there will be a major increase in the use of ceramics in heat engines in the next 15 years - yet there are already signs that the fever in this area may be subsiding (Appendix H - New York Times Article). It is undoubtedly optimistic of the newcomers to feel they can compete with the 2000 Japanese, 1000 American and 300 European researchers in ceramics ... Canada has only one school graduating ceramists and since 1970 about 70 BSc, 18 MSc and 5 PhD's have been trained - they are not all in Canada and, of those that are, not all are in research and development.

It is the writer's view that there is a massively disproportionate interest by those outside the field in structural ceramics - perhaps the promise of a ceramic engine has been oversold. The Canadian markets for such products do not presently exist and the world market is very small whereas the market for functional products is about $5 billion U.S. and rising at 15-20% /year. This gross imbalance with the present and near-term markets is reflected in the programs elsewhere initiated or continuing in 1986:

- NRC Halifax (Toughened ceramics)
- RPC, NB (Toughened ceramics)
- AECL, Chalk River (Ceramic Consulting)
- Univ Alberta new faculty position (Emphasis unknown)
- Queen's Univ. faculty positions in
  - Metallurgy (Structural ceramics)
  - Chemistry (Syntheses?)

Such unfounded faith needs tempering with reality otherwise the field as a whole will suffer considerable harm in the eyes of the money markets.

C. Technically

Influence on MSL Programs by NACMMR, CCC, CCS, DRIE, MOSST?

There is reason to believe that the Canadian Ceramics Council will become a dominant force in stating the industrial needs in the ceramics field. This should be encouraged and they should displace (at best) or be the guiding light in NACMMR. The Canadian Ceramics Society is also begining to awaken to the possibility of how to interact with the Government, c.f. Appendix F. Such industrially oriented views are welcome.

MOSST, DRIE and NRC are also falling victim to the general euphoria surrounding advanced structural ceramics noted above and this, indirectly, will bring pressure on MSL to respond. Some pressure is good and some response can be accommodated but we must remain aware of the markets and the bases on which the projections are made - in the case of Japan, the bold view of the structural markets held by Min. Int. Trade and Ind. (MITI) assumes the availability of technology that has yet to be developed.

Conference

The inability to find registration funding to attend 1986 Canadian meetings of the CCS (Appendix F), Queen's Advanced Materials Technology Unit, the CIM etc is beyond comprehension - particularly when an individual member

of staff as a Scientific Authority can authorize $5-10K/year as travel funds for contractors to attend such meetings.

Staff

Areas of technical weakness already noted in Appendix A.

WHAT OPTIONS EXIST FOR MSL?

Program Development

On the technical side, the major overall industrial concerns are product cost, reliability and durability and these, in turn, cover the whole spectrum of production concerns from security of supply for materials and energy at minimum cost to quality assurance.

Although it appears straight forward to develop a program in ceramics that covers such generic areas, in reality, the work is always product and/or material specific - a point that the policy makers have yet to appreciate. Thus data generated in one program will unlikely be widely applicable in other projects. For this reason therefore, it is necessary to select specific product/material targets that have the maximum potential for spin-off in the future and for which a market either currently exists or can be confidently anticipated.

At present, the market ratio of functional:structural ceramics is approximately 4:1 and at the most is only expected to drop to 3:1 by the year 2000. Hence, one of the guiding principles in developing the ceramics program is that the effort in these two fields should reflect the current and projected market reality and hence 70-80% of our effort in this fast growing field should be in the functional area.

It is for this reason, that the technology of zirconia fabrication is suggested: for this work leads to both a series of durable structural ceramics as well as several electrical devices for which a demand exists, i.e., the potential for pay-off in that field is much greater. The same is also true for the development of SiC-based components. In addition, for these and other materials, the capability of conducting a project from powder synthesis to device testing should be maintained, particularly for the functional materials. In the case of the structural materials, it is suggested that MSL should focus on the materials up to the stage of characterizing simple shapes such as discs and bars - the more engineering oriented work such as complex shape fabrication and testing of components in engines etc should be conducted by or jointly with NRC, PMRL and industry.

There is a need to survey and assess the current ceramics industry to generate a reliable data base. The elements of such a survey are contained in the former "Ceramics Plants in Canada" publication of the Mineral Policy Sector of EMR. Such a survey should also include an estimate of the potential industrial new-comers to the Canadian Ceramics scene - already Polysar, Magna, Esso, Kennametal, Rolls-Royce, Pratt and Whitney, Garrett, Ontario Hydro, and Alcan have not only expressed interest in ceramics but have assigned staff to keep a watching brief on the field. This latent commercial interest should be uncovered and documented - preferably under contract.

It is desirable to encourage a commercially-oriented view of the ceramics industry's needs to guide the members of the NACMMR Committee. It is believed that the members of the CCC will offer such a view.

There are other opportunities in MSL for:
- developing indigenous raw materials (zirconia, the rare earths)
- initiating an incubator program for industrial staff training;
- hosting visiting Canadian industrial scientific & production staff;
- hosting international researchers.

A. Structural Ceramic

Refractories		So far Atlas has used products of others and has used CANMET in failure analysis ... need improved nozzles.
Toughened		
SiC)	*	Technology available in-house for synthesis of fine
SiN)	*	powders;
PSZ		Technology in-house. No good above 800C. Being pursued as various composites (transformation toughening)
SiAlON	*	$300k buys the technology from Lucas-Cookson Syalon.
Composites		Fertile area with high commercial interest. Lack of some facilities such as high-temp mechanical properties. Presently developing: ZrO_2-toughened alpha- and beta-aluminas mullites BN-fibre reinforced BN-sialons TiB_2-AlN-BN
Coatings	*	Wear and corrosion resistance. Some work underway in IMRI.

* - Coatings and single-phase monolithic nitride technology will not be addressed.

B. Functional Ceramics

The ceramics group is strong in synthesis, processing, characterizing and exploiting electrical ceramics: ionics (in industry), piezoelectrics (in industry), pyroelectrics/relaxors/electrostrictives, P/NTCs, Varistors, Barrier Layer Devices etc. There is a consensus that we should retain our presence in the existing fields (ionics and piezoelectrics) and expand our horizons such as the NDT/transducer work and composites.

WHAT OPTIONS EXIST FOR MSL-PMRL CO-OPERATION?

A. Material Characterization

Electron Optics

PMRL are well-equipped to conduct sophisticated micro-structural analyses. With the scheduled installation of SIMS and the present operation of EELS they have a capability of looking at the light elements such as Li, B, C, N, O etc that lie below the lower limit of Na for the MSL microprobes. With the increasing commercial interest in the covalent materials formed using these elements (carbides, nitrides, oxides) and the MSL involvement already in some of these: BN, TiB_2, AlN, SiC and composites containing these, there is a

clear opportunity for co-operation in characterizating these materials as a function of processing and use in service.

There is also increasing commercial interest in barrier-layer devices such as varistors. In this case, there is a need for the analysis of the deliberately formed grain-boundary second-phase. Minor changes in this layer due to selective loss of a volatile component during sintering, contamination, etc has a profound influence on the electrical behaviour of the material and hence the device. The ability to monitor such grain boundaries, or the interface between a fibre/whisker and its matrix in a composite is vital to the development of many of the advanced ceramics.

These aspects were explored on a preliminary basis with members of PMRL on 20 Nov 86. Samples of SiC powder, BN fibre, sintered ZnO varistor were provided so that appropriate sample preparation techniques can be developed and experience gained in characterizing these materials.

Mechanical Properties

The facilities for mechanical testing of materials in 405 Rochester are very limited. There is a need to have the measurement of mechanical properties (Young's modulus, MOR, K_{1c}) not only at room temperature but at elevated temperature - usually in air. This was recently proposed to PMRL management.

B. Fabrication

It was agreed with D. White that PMRL should work in the area of ceramic-containing metal-matrix composites (cermets). Clearly, any assistance that could be offerred by MSL for such projects would be available where possible.

REFERENCES

1. Murthy, M.K. "Advanced Ceramics" Report No.3/86 available from the Office of Industrial Innovation, Dept Regional Industrial Expansion, Ottawa at (613) 995-3741.

2. Wheat, T.A. "Advanced Ceramics in Canada" Division Report MSL 86-64(OP&J). Paper presented to the Annual Meeting CIM, Montreal May 1986 and submitted for publication.

3. Wheat, T.A. "Ceramics Mission to Japan - March 1986", Division Report MSL 86-73(TR).

4. Wheat, T.A. "Advanced Ceramics in Japan and Canada" Division Report MSL 86-74(OP). Paper presented to the Inaugural Workshop of the Canadian Industry-University Council on Advanced Ceramics, 2-3 June 1986, Toronto.

5. Wheat, T.A. "Advanced Ceramics - Japan Today and Canada Tomorrow", Report 86-84(OP). Paper presented to a series of industrial seminars held in Montreal, Toronto and Vancouver, June 1986.

Appendix A

Profile of Ceramics Section

A. Expertise

Omissions

For over 20 years, the following areas have not been represented by any section member:

- glass
- enamel
- magnetics
- optics

Losses

During that period, we have lost expertise in

- refractories
- clay & shale, pottery and whiteware

Gains

During that period, we have strengthened

- processing (DQ/AK),
- electrochemistry (AA/JDC).
- dielectrics capability

B. Current Staff & Skills

AA	Electrochemist	PhD	RS	Electrical props, Processing
JDC	Physicist	PhD	RS	Electrical properties
AKK	Chemist	PhD	RS	Ceramic Processing, Characterization
VVM	Chemical Eng	PhD	RS	Thermal Properties
DQ	Mineralogist	PhD	RS	Synthesis, Characterization, Failure Anal
?	Ceramicist?	MSc+	PC	Synthesis, Processing, Characterization
TAW	Ceramicist	PhD	RS	Advanced Ceramics
AJH	Ceramic Tech		EG	Trad & Adv Ceramics + Instrumentation
GMcD	Ceramic Tech		EG	Thermal Props + Advanced Ceram + Instmentn
GL	Ceramic Tech		EG	Trad Ceramics + Instmentn
RS	Electronics		EL	Instrumention

Over time there has been a decreasing scientist:technologist ratio.

C. Facilities

Capital Equipment

Inadequate facilities:

- Much of the equipment has not been replaced and should have been years ago - furnace room controllers, etc.
- Not automated - essential with the decreasing scientist:technologist ratio.
- Need data acquisition -> number crunching (graphics/line fitting) -> camera-ready graphics e.g. for GA, DTA, Expansion, Strength, etc). Have technologists willing to learn.

Appendix B

Changing Markets for Exported Canadian Products

Product	% 1964	% 1984	Change
Food	22.2	9.6	--
Raw Materials	19.4	15.6	-
Finished Materials	42.2	31.6	-
Auto Parts	2.1	26.1	+++
Machinery & Equipment	9.8	12.4	+
Consumer Goods	1.8	3.0	+
Other	2.5	1.6	

p147, ref 1.

Highlights of Recommendations in Ref 1

The perspective of the report was to comment on the opportunities for advanced ceramics in Canada. The following points were noted in the executive summary:

1. There is a tremendous opportunity for the existing advanced ceramics industry to grow, not only to satisfy expanding domestic needs, but also to develop export markets.

2. Advanced ceramics will play a vital supportive role in the growth of high technology industries such as electronics, computers, telecommunications, aerospace, robotics and biotechnology.

3. Advanced ceramics hold the key to long term solutions to energy and resource industry problems.

4. Advanced ceramics will significantly improve productivity in many manufacturing industries

5. As in the United States, Japan and Europe, advanced ceramics offer the opportunity for growth and diversification in other industries.

As the author notes, **"the question is not whether Canada should invest in the development of an advanced ceramics industry; it is whether Canada can afford not to."**

Appendix C

Contribution of Section to Economy

A. Direct Gain - Piezoelectrics

At present, about 130 are employed producing and developing piezoelectrics in Canadian Industry - over 75% of which are exported, mainly to the States:

Almax	105 employees
Lakeside	15-25 depending on markets
BM Hi-Tech	6

Of these, about 7 are supported on Federal funds (IRAP - Almax & BM) - the remaining ~120 are private sector supported employees.

The oldest company is Almax (1963) which was created directly from the work conducted by EMR for DND in materials for sonars. Later, the original Almax partners (Al Ankus and Max Fallis) split and Lakeside electronics was formed in 1973 by Al Ankus. More recently, BM Hi-Tech was formed, initially as a subsiduary of Blue Mountain Pottery at Collingwood and later, in early 1985, as a division of the company Sensor, Toronto. All three companies have benefited substantially from the developmental work at EMR first initiated by Ian Wright.

Return on Investment

The following assumptions have been made for illustrative purposes - the number in parentheses are probably more appropriate and render the case more compelling:

EMR/Public Investment
70 (50) p-ys $100k/p-yithverhead — $7 million (1986$) total invested

Commercial Return
100 (130) employed earning $20k/yr — 2 million/yr returned

Assuming a conservative multiplier of 3 (4-5 usual) through the local economy, this implies that the **R&D costs have been recovered in one year of production.** No consideration has been given to the savings of UIC and other benefits that would be required assuming 80 of the 100 were unemployed. Even a return on investment within two years is very satisfactory - the remainder is pure profit to society.

B. Avoidance of Loss - Solid Electrolytes

There are many examples throughout CANMET in this class (they are also more difficult to quantify).

In the last six years, the section's own work has clearly demonstrated **contrary to the literature** the unsuitability of several materials for advanced energy systems which were under active development by NRC (Lisicons - Divn Energy) and industry (Almax - Nasicons). The effort involved about 4 p-y ($400,000 total), they could well have been part of a major development program for the Almax thermoelectric generator ($1 million total) and the Magna sodium-sulphur battery ($4.5 million so far and undoubtedly going to increase), i.e., less than 7% of the current investment in this field was used by a completely independent, non-biased group to demonstrate the poor durability of seemingly (from the literature) attractive materials for these applications.

C. Technology Transfer - Consulting

This is the most difficult area to quantify - the extensive consultations that are given to all levels of Government, PRO's, Universities, and industry. However, it is none-the-less significant. Recent work on refratories for Atlas Steels, the extensive and excellent work in the Clay and Shales of ... that has been used widely, the work currently underway to develop BN-BN composites in industry, the co-operative efforts in glass-metal seals with ORF and Quality Hermetics, the extensive IRAP etc work conducted for other Departments etc - see Appendix E.

Also to be included, are the contributions made to other organizations such as members of CGSB, input to CSA, numerous officers to the Canadian Ceramics Society (three Presidents, two Editors, and a number of Divisional Chairmen and Secretaries) and, more recently, the **invited** contributions to the technical programs of the CIM, CCS, Canadian Ceramics Council, and the industrial seminars of External Affairs. Such contributions are real but remain difficult to quantify.

Appendix D

Ceramics Program in MSL - 1986/87

I. Collaboration with External Organizations

Technology	Organization	Funded by
Ultrasonics	Lakeside Elect	NRC
NDT Transducers	BM Hi Tech Inc	NRC
Sonars, etc	Almax Ind Ltd.,	NRC
Sodium-Sulphur Battery	Powerplex Tech	EMR/NRC
Thermoelectric Generator	Almax Ind Ltd.,	NRC
Sensor for Zn in Pb	NB Min & Smelting	NRC
Tritium Pump, etc	CFFTP, AECL	
Sensor for Oxygen	U Western Ont	EMR
Toughened Ceramic	McMaster U	EMR
BN Composites	Electrofuel Manuf. Co.	EMR
Glass & Ceramic Seals	Quality Hermetics	NRC
Investment Cast. Moulds	Design Precision Cast.	EMR
Fluoride Emmissions	Pollutech/Clay Brick Man	EMR
Iron Ore Processing	Iron Ore Co. Canada	
C Electrode	Atlas Steel	
Cr-Mg Refractory	Atlas Steel	
MgO-C Refractory	Atlas Steel	
Thermal Props Rocks	AECL	
Standards	Purdue U	
	Univ Orleans, France	

II. Internal Program

Na-Conducting Electrolyte
- Beta-aluminas
  - Effect of Processing & Composition on Properties

H-Conducting Electrolyte
- Beta-alumina & Zirpsios
  - Composition and Processing vs Behaviour
  - Electrical & Microstructural Characterization
  - Device Applications

Electrode Systems
- Synthesis and Deposition of Electrodes
- Electrical and Microstructural Characterization
- Assemble Lab scale Fuel Cell, Sensor, Pump

Structural Ceramics
- Synthesis & Characterization of Toughened Alpha- and Beta-alumina
- Synthesis and Characterization of SiC

Characterization of Materials
- Fractal Analysis of Ceramic Systems
- Automate Characterization of Ceramic Dielectrics
- Automate Thermal Conductivity Measurement

Appendix E

Industrial Programs Having Ceramic Section Input

I. National Research Council

A. Industrial Research Assistance Program - IRAP

1. SAM 265 "Microstructural Studies on Abrasive Materials"
   Norton Co. 1974-1976

2. SAM-261 "Development of High-Purity Electrolytic Alumina"
   Northern Pigment Co. Ltd. 1974-1978

3. ALUMINA 415 "Fine Grained Alumina Substrates for Micro-Circuit Applications"
   Lakeside Electronics Ltd., 1976-1979

4. PIEZO 518 "New Piezoelectric Ceramics for Modern Electronics Applications"
   Almax Industries Ltd., 1978-1980

5. PZT 546 "Development of Air-Coupled Transducers"
   Milltronics Ltd., 1978-1980

6. HERMETIC 696 "Research Into Materials for Use In Hermetic Seals"
   Quality Hermetics 1979-1981

7. CERMET 652 "Conductive Cermet Pastes"
   Lakeside Electronics Ltd., 1979-1982

8. SAWCER 1302 "Study of Compositions for SAW and Nasicon Ceramics"
   Almax Industries 1981-1984

9. HISEAL 1389 "High-Temperature, High-Pressure Hermetic Seal"
   Quality Hermetics 1981-1984

10. M "Slip-cast Alumina Products"
    Home Technics Ltd 1982-1983

11. M598 "High-alumina Technical Ceramics"
    Home Technics 1983

12. HMULP 1818 "Hot Moulding Ceramics under Low Pressure"
    Lakeside Electronics Ltd., 1983-1986

13. PZCER 2023 "Development of Piezo Electric Ceramics for Transducers"
    BM Hi-Tech Inc., 1983-1986

14. Na/S 2151 "North American Sodium Sulphur Research Program"
    Powerplex Technologies Inc 3 years

B. Program of Research Assistance to Industry - PRAI

15. S-14 "New Electrochemical Sensors"
    Leigh Instruments Ltd.,
    University of Toronto 1973-1975

16. P8310 "Development of a Probe to Monitor Zinc in Liquid Lead & Silver"
    New Brunswick Mining & Smelting
    University of New Brunswick 1983-1986

C. Division of Energy - DOE

17. 080-152/0-6617 "Construction of Ceramic Electrolyte Test Cells and Preliminary Tests"
    McMaster University 1980-1982

18. 06SX.31155-0-6606 "Lithium Ion Conductors"
    Ontario Research Foundation 1980-1981

19. 05SU.31155-1-6628 "Evaluation of Performance and Lifetime of Ceramic Electrolyte Test Cells"
    McMaster University 1981-1984

D. Pilot Industry-Lab Program - PILP

20. CA-155-1-0723/1068 "Sodium Ion Electrolytes"
    Almax Industries Ltd., 1982-1986

II. Department of National Defence - Defence Research Board

Defence Industrial Research - DIR

21. E-142 "Development of Magnetic Oxides"
    Northern Pigment Co. Ltd. 1970-1975

22. E-232 "Development of Lithium Niobate Single Crystals"
    Northern Pigment Co. Ltd., 1970-1975

23. E-188 "Pressure Stable Low Aging Transducer Compositions"
    Sinclair Radio Labs. Ltd. 1973-1975

24. E-237 "Development of Thin Sheet Piezoelectric Ceramics"
    Lakeside Electronics Ltd., 1973-1976

III. Department of Industry, Trade & Commerce

25. DIP - #9ST76-00004 "Development of Piezoelectric Compositions and Processes"
    Almax Industries Ltd., 1975-1978

26. IMDE - #45/513A-E-43-10 "Program for the Establishment of a Canadian Source for Subminiature Ceramic EMI Filters and the Ceramic Elements of such Filters"
Erie Technological Products Ltd., 1977-1980

IV. Department of Energy, Mines & Resources

Research Assistance Program and Dept Supply & Services Contracts

27. RAP - #2239-2-149-77 "Production of Beta"-Alumina Electrolyte for the Sodium Sulphur Battery"
McMaster University 1977-1978

28. DSS - #03SU.23440-7-9115 "Study of the Production of High-strength, High-conductivity Beta-alumina by a Slip-casting, Low-temperature Firing Process"
McMaster University 1978-1979

29. RAP - "Production of Beta"-alumina by a Slip-casting Process"
McMaster University 1979-1980

30. RAP - #218-2-80 "Sodium Superionic Conducting Ceramics in the Na_2O-Gd_2O_3-SiO_2 and Na_2O-Y_2O_3-SiO_2 Systems"
McMaster University 1980-1981

31. RAP - #128-2-81 "Sodium Superionic Conducting Ceramics in the Na_2O-Gd_2O_3-SiO_2 and Na_2O-Y_2O_3-SiO_2 Systems"
McMaster University 1981-1982

32. DSS - #1SQ78-00234 "Development of Sodium Solid Electrolyte Ceramics and Evaluation of Their Suitability in Energy Conversion and Storage Devices"
Almax Industries Ltd.,
Ontario Research Foundation 1979-1981

33. DSS - 20SU.23440-0-9006 "The Development of Non-destructive Testing Techniques to Evaluate the Integrity of Sintered Solid State Electrolytes"
McMaster University 1980-1982

34. DSS - 20SU.23440-0-9076 "Characterization of Three Dimensional Fast Ion Electrolytes Using Nuclear Magnetic Resonance"
Queen's University 1981-1982

35. DSS - 23SQ.23440-1-9051 "Review of Progress in Solid Electrolytes"
ASCOR Consulting 1981-1983

36. DSS - 23SU.23440-1-9096 "Equipment and Methodology for the Automated Conductivity Testing of Ceramics"
Queen's University 1981

37. DSS - 20SU.23440-1-9104 "Production of Sodium and Hydrogen Ion Conducting Silicates by Spray Drying - Phase I"
McMaster University 1981-1982

38. DSS - 01SU.23440-1-9105 "Development of Proton Conductors"
Queen's University 1981-1983

39. DSS - 20SU.23440-2-9065 "Development of Non-destructive Testing Techniques to Evaluate the Integrity of Sintered Solid State Electrolytes - Phase II"
McMaster University 1982-1983

40. DSS - 22SU.23440-3-9080 "Durability of CANMET-produced Electrolytes"
McMaster University 4 months (1983)

41. DSS - 24ST.23440-3-9129 "Develop Electrodes for Fuel Cell - Phase I"
Queen's University 1983-1984

42. DSS - 20SU.23440-3-9130 "Development of NDT Techniques to Evaluate Sintered Solid Electrolytes - Phase III"
McMaster University 1983-1984

43. DSS -03GR.23440-3-9232 "Patent Services for Advanced Energy Conversion Materials"
Mitches & Co. 1984-1985

44. DSS - 24ST.23440-4-9175 "Non Destructive Testing of Solid Electrolytes"
McMaster University 1984-1985

45. DSS - 21ST.23440-4-9204 "Develop Electrodes for Fuel Cell - Phase II"
Queen's University 1984-1985

46. DSS - 03SQ.23440-4-9223 "Characterization of Thin Films Used as Electrodes in Electrochemical Devices"
Ont Res Foundation 1984-1986

47. DSS - 03GR.23440-5-9084 "Patent Services for Bonded Ceramic Materials"
Mitches & Co. 1985-1986

48. DSS - 03SQ.23440-5-9226 "Development of Composite Materials"
Electrofuel Inc. 1985-1987

49. DSS - 15SQ.23440-6-9102 "Develop High Resolution Transducers for NDE"
BM Hi-Tech Inc. 1986-1987

Appendix F

Canadian Ceramic Society
Fall Meeting, 7 Oct 1986, Toronto

PROGRAMME

10:00 am – 12:00 noon
Speakers

Energy Monitoring and Management

Mr. A.E. Paz P.Eng.
Manager (Energy and Environmental Control)
Nabisco Brands Ltd.

Mr. Paz has extensive experience in the development of energy management systems involving automatic control at Nabisco.

Energy Pricing and Supply

Mr. T. Bjerkelund
Executive Director
Industrial Gas Users Association (IGUA)

Mr. Bjerkelund is executive director of an influential body concerned with policy and pricing with respect to natural gas.

12:00 noon — 1:30 p.m.
Lunch

The Society has extended an invitation to
Mr. Frank Oberle
Minister of State for Science and Technology
to speak at lunch.

1:30 pm – 3:00 pm
Panel Presentation

Technology Requirements in the Canadian Ceramic Industry

The Glass Industry
– Mr. Leiven Gaevert – Consumers Glass

Manufacturing
– Mr. K. El-Assal – Almax Industries Ltd.

Resources and Opportunities

Ceramics – The Government View
– Dr. Graham Taylor (MOSST)

The Canadian University
Industry Council on Advanced Ceramics
– Dr. Peter McGeer – Alcan

New Materials and the CMA Initiative
– Dr. Ivan Joyce, ORF

3:15 pm – 4:30 pm
Panel and General Discussion

The role of the Canadian Ceramic Society

Appendix G

University-Industry Council on Advanced Ceramics

Founding Members

Dr P.S. Nicholson, McMaster University Dr. M. Sayer, Queen's University
Dr A.C.D. Chaklader, UBC Dr M. Rigaud, Ecole Polytechnique*
Dr H. King, TUNS

* Replaces Levelton & Associates Rep on NACMMR Committee

Alcan International Ltd.,	Almax Industries Ltd.,
Atomic Energy Canada Ltd.,	BM Hi Tech Inc.,
Centre de Recherche Noranda	Esso
EYC Technical Ceramics Inc.,	Fiberglas Canada Ltd.
Foseco Canada Inc.	Garrett Canada
Hamilton Porcelains Ltd.	Hatch Assoiates Ltd.
Howden Group Canada Ltd (Brown Boveri)	Inco Ltd.
Industrial Ceramics Ltd.	IVI Inc.
Kennametal Inc.	Murata Erie North America Ltd.
Ontario Hydro	Polysar Ltd.
Powerplex Technologies (Joint Venture: Magna/Brown Boveri)	
Pratt & Whitney Canada Ltd.	Rolls Royce Canada Ltd.
Synergetics Technologies	The Electrofuel Manufacturing Company
Tioxide Inc.	**26 Companies**

Board Members

Dr P.S. Nicholson	President	McMaster U
Dr P. McGeer	Chairman	Alcan
Dr M.K. Murthy	Sec-Treas	MKM Intl
A.C.D.Chaklader		Univ BC
H. King		Tech Univ NS
K. Linger		Fiberglas Canada
R. McEwen		EYC Tech Ceramics
M. Rigaud		Ecole Polytechnique
M. Sayer		Queen's Univ
C. Simpson		Ont Hydro
J. Zachary		Rolls Royce

Objectives

- Promote, Foster and Focus the Development of Advanced Ceramics in Canada
- Ensure and Contribute to The Establishment of National Goals for Advanced Ceramics
- Promote Broader Understanding in Canada of International Advanced Ceramics Activities
- Promote Awareness of Canadian Achievements both Nationally and Internationally
- Increase Awareness of the Strategic Importance of Advanced Ceramics

Appendix H

Cooling of Japanese Interest in Automotive Ceramics?

INTERN

Ceramic Engines Losing Support in Japan

By Stephen Kreider Yoder
Staff Reporter of The Wall Street Journal

TOYOTA CITY, Japan—In a back room here at Toyota Motor Corp.'s headquarters, a ceramic engine has been gathering dust for four years.

Toyota built the engine in the early 1980s, when the automotive world thought ceramics would soon replace steel inside car motors. The notion caught the fancy of car enthusiasts around the world, and the news media widely predicted a ceramics revolution that would produce powerful yet fuel-sipping engines that wouldn't need radiators.

But Toyota found that ceramic engines didn't live up to expectations. "We studied them for a long time," says Ryozo Ito, general manager of Toyota's technical-planning office. "But we weren't able to get favorable results." So Toyota, Japan's largest auto company, abandoned its ceramic-engine program.

Sharply Divided

After several years of research, auto makers here are sharply divided on the future of ceramics in engines. A few, notably Isuzu Motors Ltd., still argue that ceramic engines are just around the corner. Most makers already use ceramics for specialized engine parts. But Japan's biggest auto companies say they don't expect to see ceramic engines widely used in cars before the next century, if ever. Ceramic engines have proved expensive, fragile and inefficient. And some makers even question the theories that led to research in the first place.

The idea of a ceramic engine "was mostly an illusion," says Takane Ito, a Nissan Motor Co. engineer. "Everyone made a lot of noise about it without doing their homework . . . . But there aren't any simple solutions lying around. Whichever way we turn, there are only bottlenecks."

Makers such as Toyota and Nissan haven't given up on ceramics entirely. But they have retrenched to look for less-sweeping but more-practical applications for ceramics outside engines, in parts such as seals and turbocharger blades.

Ceramic parts for engines were supposed to do amazing things. Using the material to line cylinders and cap pistons, engineers expected to design engines that wouldn't need cooling systems and would cut energy consumption and raise power. ("Ceramic engine" is a misnomer, because only certain internal parts would be ceramic. The rest of the engine and the housing would be steel or aluminum.)

Wasting Energy

The dream was to create an engine that didn't waste energy in the form of heat. A conventional engine running at 390 degrees Fahrenheit loses more than one-third of its energy in the heat that goes to the radiator. But by insulating an engine with a material that can withstand temperatures in excess of 1,800 degrees, so the theory goes, energy normally lost in a conventional engine would be redirected as extra horsepower.

Engineering ceramics withstand temperatures that quickly turn metal into goo. As a bonus, some ceramics are more "slippery" than metal, allowing the theoretical engine to run without oil. And with no radiator to build around, car designers expected to be able to create currently unthinkable body styles.

The idea for a ceramic engine surfaced when the U.S. Army sought to camouflage military trucks from heat-seeking missiles. The army wanted a truck without a radiator, and Cummins Engine Co. of the U.S. began research in 1972 that resulted in a ceramic engine three years later.

The Cummins engine never went into production, but the Japanese picked up on the idea and began the push to commercialize it in the early 1980s, when the engines seemed attractive because of their fuel savings. Ceramics makers did all they could to encourage them. Says Mazda Motor Corp. engineer Jun Miyata: "The ceramics makers were waving the flag harder than anyone."

Decidedly Low-Key

But while some companies continue to sing the praises of ceramic engines, many auto and ceramics makers have become decidely low-key about their projects. "It's been very hard to admit that it doesn't work," says Toyota's Mr. Ito.

Ceramics simply haven't cooperated. Some types are good insulators. Others stay tough at high temperatures. In the early 1980s, engineers expected breakthroughs that would lead to ceramics that did both. It hasn't happened. "One of the biggest problems today," says Roy Kamo, who started the Cummins project but has since left the company, is that "you don't have materials that will do the job."

Today's ceramics won't stick well to aluminum and steel and are about 100 times more brittle than steel. And the materials are prohibitively expensive.

What's more, the quality of identical parts varies widely; defect rates are as high as 50%. "The reliability level is completely unacceptable for mass production," says Nissan's Mr. Ito.

But the biggest problems are even more fundamental. Engineers found early on that high temperatures make the engines knock, and cause incoming air to expand so much that the engine can't draw in enough oxygen to burn fuel correctly. To make matters worse, Nissan's and Toyota's experimental ceramic engines put out more pollutants, in some cases as much as 25% more. "We've run aground," says Nissan's Mr. Ito. "It's a deadlock both in hardware and in theory."

The Pressure Is Off

Falling oil prices also have helped damp ceramic-engine programs. "The pressure to save on fuel efficiency isn't there right now to balance the huge capital investment on a very expensive vehicle," says Francis Moyer, a securities analyst in Tokyo with W.I. Carr, Sons & Co.

Isuzu engineers think otherwise. The company has five experimental ceramic engines ranging from 1.8 to 9.8 liters and has run them a total of 3,500 hours "without any problem," says Hideo Kawamura, the engine-development manager. Isuzu expects to put ceramic engines in production cars in the 1990s.

Despite their optimism, though, Isuzu engineers concede they need some breakthroughs to find the ideal ceramic at a cheap price.

Ironically, ceramics may have the best chance in the rotary engine. Mazda, the only company in the world still building the engine, which uses triangular rotors instead of pistons, says the gasoline-powered rotary is immune to many of the problems encountered by piston-engine versions of ceramic engines. Early this year Mazda ran its first ceramic prototype for 22 hours without problems.

Company engineers give the 1990s as a possible commercialization time. "But whether it has cost-efficiency merits, we don't know yet," adds Mazda's Mr. Miyata.